An Adaptive Motion Estimation Technique Using Temporal Continuity of Motion

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Abstract

Fast block motion estimation technique is proposed to reduce the computational complexity in video coding. In the conventional methods the size of search region is fixed. For small motion regions like background the small size of search region is enough to find a block motion. But for active motion regions the large size of search region is preferred to figure out the accurate motion vector. Therefore, it is reasonable that a block motion is estimated in the variable search region (both the size and the position of it). That is to say, the search region varies according to the predicted motion characteristics of a block. The block motion in video frames has temporal continuity and then the search region of a current block is predicted using the block motion of previous blocks. The computational complexity of the proposed technique is significantly reduced with a good picture quality compared to the conventional methods.

1. Introduction

The motion estimation and compensation is a core technique in a video coding and it makes high compression rate of digital image data possible. But the motion estimation is a burden in encoding process. Block matching algorithm (BMA) is widely used since it is simple and has a good performance. Predictive motion estimation methods [1]-[4] using the spatial or the temporal correlation among the motion vectors of neighbor blocks were proposed and they outperform the full search algorithm (FSA). In these methods, the motion vector of a current block is predicted using a 2-d autoregressive (AR) model and then the position of the search region is changed. The motion of the current block is estimated in the search region of the predicted position. Only one predicted motion represents the motion characteristics of the current block in these predicted methods.

Most of video frames are background and the block motion in that area is inclined to be small and uniform. Therefore, a narrow search region is enough for that area. But the motion estimation results of objects in a video frame have a great influence on the amount of displaced frame difference (DFD) energy and coding efficiency. A wide search region must be set up for an active motion since the block motion of an active object and its neighbors tends to be irregular and large.

We present an adaptive motion estimation technique that the search region of a block varies according to a predicted motion of it. The predicted motion of the block is found using the temporal neighbor blocks of it. Both the position and the size of search region of a current block is estimated and the motion of it is found out in that region. When compare with FSA and the predictive motion estimation methods, the proposed technique represents significantly reduced computational complexity and superior video quality.

2. The proposed adaptive motion estimation

A block motion has a tendency to be temporally continuous for consecutive frames. Suppose that there is a block in the (k-1)th frame which has an actual motion of **V** from its position in the (k-2)th frame. In the kth frame, the block is then expected to be the moved position as much as **V** from that in the (k-1)th frame (Fig. 1). Furthermore, the motion vectors of temporal neighbor blocks are some grounds for identifying the motion vector of the current block. Among the temporal neighbor blocks there are some blocks of which the moving direction heads toward the reference block and the motions of those blocks are available to predict the motion of the current block. In the proposed technique, a global search region (GSR) is firstly set up like in FSA. And then a local search region (LSR) is predicted using the motion vectors of the corresponding temporal neighbor blocks. The size of LSR is variable according to the motions of the neighbor blocks and that of GSR is wide and fixed. The position of LSR is compensated as much as the motion vectors of the corresponding neighbor blocks and the range of LSR vary according to that also.

Let LSR that corresponds to a temporal neighbor block B_t be defined as S_t . Then the size of S_t is $(2 \cdot H_t + 1) \times (2 \cdot W_t + 1)$ and H_t and W_t is as follows:

$$H_t = |mv_t^v| + d \qquad (1)$$
$$W_t = |mv_t^h| + d$$

where, the motion vector of B_t is $[mv_t^v, mv_t^h]^{\mathrm{T}}$ and d is an offset that prevents the search range from being zero. The region that GSR and LSRs are overlapped becomes a new predicted search region. Most of LSRs are similarly located in GSR for a uniform motion area, while LSRs are scattered for an active motion area. The new predicted search region reasonably represents the motion characteristics of the reference block. Motion estimation is then performed with the predicted search region. Fig. 2 represents the proposed technique. Firstly GSR of current block is given as FSA and then LSR that predicted by the motion of temporal neighbor blocks is found. Each element of search point matrix is search point. The block motion is estimated only to the set element of the search point matrix.

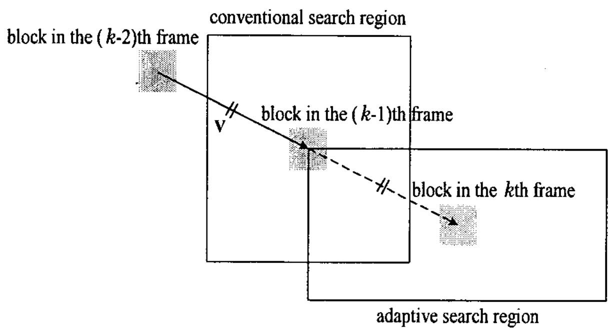

Fig. 1. Adaptive search region

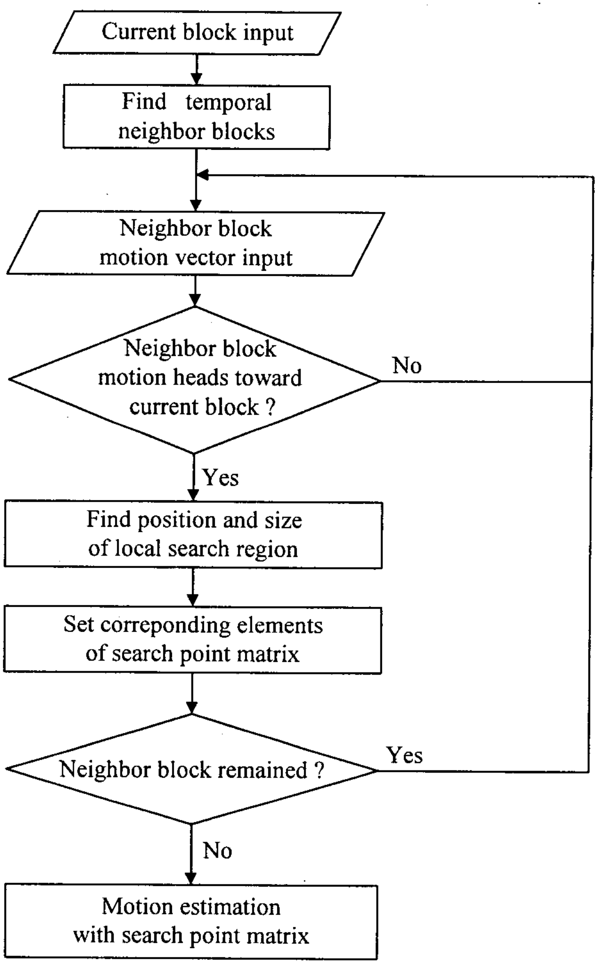

Fig. 2. The flowchart of the proposed motion estimation technique.

3. Simulation results

The proposed and the conventional algorithms are simulated using the luminance component of the various image sequences, "Football", "Table tennis", "Flower garden", and "Mobile and calendar". The size of each frame is 240×352 pixels (SIF) quantized uniformly to 8 bits. Mean absolute error (MAE) is used as a distortion measure for block matching and the block size is 16×16. The range of GSR of the proposed algorithm is ±15 pixels in both the vertical and the horizontal directions. The range of LSR is variable according to the predicted motion and we fixed the offset d as 2. The proposed algorithm is compared with FSA and the predictive motion estimation algorithms. We compare the proposed technique with two FSAs, FSA1 and FSA2. The search range of FSA1 is ±15 pixels and that of FSA2 is ±7 pixels in both the vertical and the horizontal directions. The predictive motion estimation algorithms, which are inter-block and inter-frame predictive motion estimation methods (IBPME[1],[2] and IFPME[3]), are compared with the proposed algorithm also. The search range of IBPME and IFPME is fixed as ±7 pixels.

The average complexity and the average PSNR comparisons are shown in Table 1 and Table 2, respectively. We let the complexity of FSA1 as 100% and represent that of other algorithms as a relative amount in Table 1. Since "Football" and "Table tennis" sequences have fast and large motion, they need the wide search range. But a small search range is enough for background even in those sequences. The average complexity of the proposed algorithm is reduced to 7.8-13.1% for them. Most of "Flower garden" and "Mobile and calendar" sequences have regular motion and a narrow search range is enough for them. As shown in Table 1, the average complexity of the proposed algorithm is significantly reduced to 3.6-6.0% for them.

The proposed and the conventional algorithms are about the same PSNR for the uniform motion image like "Flower garden" and "Mobile and calendar" as shown in Table 2. But the proposed algorithm exceeds the conventional ones (except FSA1) in PSNR for an active sequence like

Table 1. Average complexity comparisons of the proposed and the conventional algorithms

%

Sequences	FSA1	FSA2	IBPME	IFPME	Proposed
Football	100.0	23.4	23.4	23.4	13.1
Table tennis	100.0	23.4	23.4	23.4	7.8
Flower garden	100.0	23.4	23.4	23.4	6.0
Mobile and calendar	100.0	23.4	23.4	23.4	3.6

Table 2. PSNR comparisons of motion compensated image of the proposed and the conventional algorithms

[dB]

Sequences	FSA1	FSA2	IBPME	IFPME	Proposed
Football	22.59	21.93	22.21	22.20	22.32
Table tennis	29.48	28.91	29.01	29.03	29.07
Flower garden	25.25	25.24	25.24	25.24	25.24
Mobile and calendar	23.43	23.43	23.43	23.43	23.43

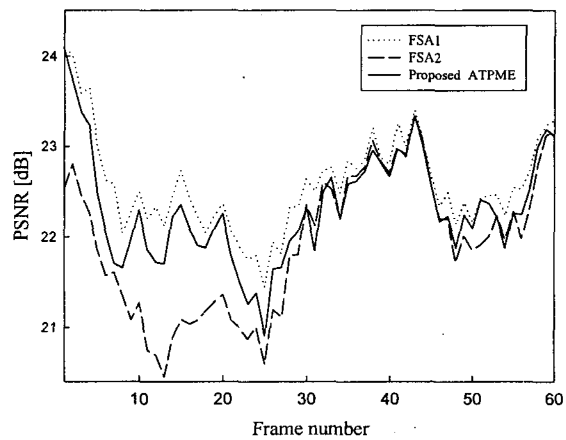

Fig. 3. Comparisons of frame PSNR for "Football" sequence

"Football" and "Table tennis". Fig. 3 represents the comparison of frame PSNR for "Football" sequence. The proposed algorithm shows an excellent results extending over all frames. From the above results, the adaptive motion estimation technique makes a search region be suitable to a block motion and it executes a trade-off between the complexity and PSNR. The complexity is significantly reduced in a quiet motion image and PSNR is raised in active motion image when compared to the conventional block motion estimation techniques

4. Conclusions

We present an adaptive motion estimation technique that the search region of a block varies according to a predicted motion of it. The motion of a current block is predicted using the temporal neighbor blocks of it. Both the position and the size of search region of that is predicteded and the motion of it is found out in that region. Comparing with the conventional methods, the proposed technique represents significantly reduced computational complexity and a good picture quality.

References

[1] C.-H. Hsieh, P.-C. Lu, J.-S. Shyn, and E.-H. Lu, "Motion estimation algorithm using interblock correlation," IEE Electronic Letters, Vol. 26, pp. 276-277, Mar. 1990.

[2] S. Zafar, Y.-Q. Zhang, and J. S. Baras, "Predictive block-matching motion estimation for TV coding--Part Ⅰ: Inter-block prediction," IEEE Trans. Broadcasting, Vol. 37, pp. 97-101, Sept. 1991.

[3] Y.-Q. Zhang, and S. Zafar, "Predictive block-matching motion estimation for TV coding--Part Ⅱ: Inter-frame prediction," IEEE Trans. Broadcasting, Vol. 37, pp. 102-105, Sept. 1991.

[4] L. Luo, C. Zou, X. Gao, and Z. He, "A new prediction search algorithm for block motion estimation in video coding," IEEE Trans. Consumer Electronics, Vol. 43, pp. 56-61, Feb. 1997.